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MR ERNEST GOLD, C.B., D.S.O., O.B.E., F.R.S.

With the passing of Mr Ernest Gold on 30 January at the age of 94, meteorology lost one of its outstanding figures, the Royal Society its senior Fellow, and the Meteorological Office a former second-in-command who dominated the scene for a quarter of a century.

After a brilliant career in mathematics and physics at St John's College, Cambridge, Gold joined the Meteorological Office in 1906 only to return to Cambridge the following year as Schuster Reader in Dynamical Meteorology at the tender age of 26. It was during the next three years that he published his historic explanation of the newly discovered stratosphere in terms of radiative equilibrium involving both water vapour and ozone. Another of his early papers, published in 1908, on barometric gradient and wind force is also a classic. These outstanding contributions were recognized by his election to the Royal Society in 1918 at the early age of 37.

In 1910 Gold relinquished his Readership and returned to the Meteorological Office where he remained until his retirement in 1947. During those 37 years his influence and example on both the national and international scene were immense. In the First World War he commanded the contingent of meteorologists with the British Forces in France and emerged as Lieutenant-Colonel Gold, decorated with the D.S.O. and O.B.E. For the next 20 years, as Assistant Director, he was largely responsible for building up a forecasting service to meet the rapidly growing requirements of aviation and played a leading role in putting synoptic meteorology on a firm international basis. As President of the Commission for Synoptic Weather Information of the International Meteorological Organization (IMO) from 1920 to 1947 he probably did more than anyone else to organize an efficient world-wide system for the collection, coding and exchange of meteorological observations. He was also President of the Meteorological Sub-commission of the International Commission for Aerial Navigation from 1922 to 1946 and a member of three other IMO Commissions. His outstanding services to international meteorology were fittingly recognized by the award of the International Meteorological Organization Gold Medal and Prize in 1958. His scientific contributions were further acknowledged by the Symons Memorial Gold Medal of the Royal Meteorological Society of which he was President in 1934–35.

During the Second World War Mr Gold, as Deputy Director of a greatly expanded Meteorological Office, carried a heavy responsibility for providing meteorological services for the British Forces throughout the world. His

knowledge and experience, and his firm adherence to scientific principles ensured that the technical standards of British military meteorology were unrivalled. These contributions were recognized by the award of the Companionship of the Bath in 1942 and the American Medal of Freedom with Silver Palms in 1946.

Gold's was a very strong personality, revered and perhaps a little feared by his subordinates who could never be sure that the slightest error would escape his eagle eye. His stream of personal memoranda and instructions on all aspects of weather forecasting are still indelibly printed on the minds of the dwindling band of recipients who survive their originator.

When I first met Mr Gold he was already retired from public service but I shall always remember his abiding enthusiasm for the subject and his kindness and encouragement to me as a young man. I can see him now in the front row at meetings of the Royal Meteorological Society, apparently asleep, but rising to his feet, hand on hip, to put a sharp, pertinent question to a brash young scientist and complaining 'But, Mr President, Dr . . . has not answered my question. What I wanted to know was this. . .'. At one of his last public appearances, at a lecture by an Apollo astronaut at the Royal Society, he delighted the audience by saying that he wished he could have been on the Moon a few days earlier when he had fallen out of a pear tree and could have wished for a substantial reduction in the gravitational force! He was indomitable and kept his enthusiasm for meteorology and his impish sense of humour to the end.

B. J. MASON

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THE QUASI-BIENNIAL OSCILLATION IN TROPICAL STRATOSPHERIC WINDS: A METHOD OF FORECASTING

By B. N. PARKER

SUMMARY

Wind data for Canton Island and Gan at 30 and 50 mb are used to show a significant tendency for some events in the tropical stratosphere to occur near a particular time of year. Tests on linear regressions of the length of a period on the number of the month in which it began also show a significant relationship. Linear regressions of the rate of downward transmission of events from 30 to 50 mb on the month of the 30-mb event and of the lag between temperature and wind events on the month of the wind events are presented. A method of forecasting future cycles is described.

The oscillation in the zonal wind component which is most marked between 30 and 50 mb near the equator is one of the surprises of modern meteorology, in that before its discovery (Ebdon (1960) and Reed (1960) produced papers at about the same time) there was no prediction of its existence on dynamical grounds. This might perhaps lead one to assume that there is no necessity to take notice of it in general forecasting procedures or, in particular, in building numerical models of the general circulation, on the presumption that it has no discernible effect on the state of the rest of the global atmosphere. That this assumption is unwarranted may be gathered from Böhme (1969), Godson (1964),

Kats (1964) and Ebdon (1972 and 1975). In particular the Ebdon (1975) paper produces convincing relationships between the phase of this oscillation and the latitude of the maximum zonal wind speed at 500 mb—a factor which strongly influences the weather over wide areas, and in particular affects summers in the United Kingdom.

These publications established an interest in what has come to be known as the quasi-biennial oscillation (QBO) and relationships from some of them (e.g. Ebdon (1972 and 1975) and Bugayev *et alii* (1972)) might provide useful tools for forecasting the weather for the United Kingdom and Russia over extended periods if one had the necessary knowledge of future phases of the QBO.

To this end a study was initiated which used as basic data the monthly mean wind velocity at Canton Island (2° 46′S, 171° 43′W) from October 1953 to August 1967 and at Gan (0° 41′S, 73° 09′E) from September 1967 to May 1975. From these values the mean zonal wind component, $\bar{u}$, was computed for each month. The date of change-over from westerly to easterly was defined as the first month of easterly and that from easterly to westerly as the first month of westerly, and the dates of four events were extracted for each cycle: maximum westerly component ($D_{W\max}$), westerly to easterly change-over (D_{W-E}), maximum easterly component ($D_{E\max}$) and easterly to westerly change-over (D_{E-W}). At this stage histograms of frequency of occurrence of events in each month were plotted, and from these Table I was derived. It demonstrates the tendency for events to occur at a given time of year. At 30 mb, 16 change-overs occurred in the period January–June and only 3 in the remaining months July–December, whereas at 50 mb the downward transmission retarded the peak to 16 in April–September, leaving 3 in October–March. It is difficult to establish in these circumstances which particular statistical test is appropriate. Owing to the cyclic form of the data the Kolmogorov–Smirnov one-sample test does not apply and it would appear that despite Siegel (1956), this is one instance in which the chi-square test fits the requirements better. The chi-square test was used to measure the difference between the observed distribution of dates on which events occurred and a random distribution which was assumed to be an equal number in each four-monthly period. The results show the distribution of 50-mb and 30-mb change-overs to be significantly different at the 1 per cent level from an equal number in each four-monthly period. The maxima are not so highly organized, perhaps because there is at times some difficulty in dating them accurately, and at 50 mb their distribution is not significantly different from random. At 30 mb, however, the 5 per cent level is attained.

There is then a strong basis for supposing that some events tend to occur near a given time of year and it was thought possible that a variation in the date of an event might affect the length of the interval between it and subsequent events. As a first step towards investigating this hypothesis a series of scatter diagrams was plotted, each relating the month in which an event occurred to the length of the following cycle, half-cycle, phase or arc (see Table II for definitions of these terms).

Figure 1 shows the scatter diagram for the increasing westerly arc at 30 mb and it may be seen that the points cluster in the early part of the year with intervals of moderate length, but those arcs starting in June and August were very short, hinting at a trend for decreasing arc lengths with later dates of commencement.

TABLE I—PREFERENCE OF STRATOSPHERIC EVENTS AT CANTON ISLAND (OCTOBER 1953 TO AUGUST 1967) AND AT GAN (SEPTEMBER 1967 TO MAY 1975) FOR OCCURRING AT A PARTICULAR TIME OF YEAR.

Months in which event occurred	D_{W-E}		D_{E-W}		either change-over		χ^2		Significance level	
	Number of change-overs									
	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb
Jan.–Apr.	6	1	7	2	13	3				
May–Aug.	2	7	2	6	4	13				
Sept.–Dec.	1	2	1	1	2	3	10·8	10·5	1%	1%

Months in which event occurred	$D_{W max}$		$D_{E max}$		either maximum		χ^2		Significance level	
	Number of maxima									
	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb	30 mb	50 mb
Jan.–Apr.	0	1	1	4	1	5				
May–Aug.	6	7	3	2	9	9				
Sept.–Dec.	3	2	6	3	9	5	6·7	1·7	5%	—

TABLE II—DEFINITIONS OF TERMS USED TO DESCRIBE PORTIONS OF A CYCLE IN TROPICAL STRATOSPHERIC WINDS.

Interval	From	To	Schematic shape
1. Whole cycle	(a) D_{E-W}	D_{E-W}	
	(b) $D_{W max}$	$D_{W max}$	
	(c) D_{W-E}	D_{W-E}	
	(d) $D_{E max}$	$D_{E max}$	
2. Phase			
(a) westerly	D_{E-W}	D_{W-E}	
(b) easterly	D_{W-E}	D_{E-W}	
3. Half-cycle			
(a) westerly to easterly	$D_{W max}$	$D_{E max}$	
(b) easterly to westerly	$D_{E max}$	$D_{W max}$	
4. Arc			
(a) decreasing westerly	$D_{W max}$	D_{W-E}	
(b) increasing easterly	D_{W-E}	$D_{E max}$	
(c) decreasing easterly	$D_{E max}$	D_{E-W}	
(d) increasing westerly	D_{E-W}	$D_{W max}$	

Note. The illustrative diagrams in the final column follow the conventions used throughout; 'westerly' means *from* the west, and is plotted as positive. The horizontal lines represent zero $\bar{u}$.

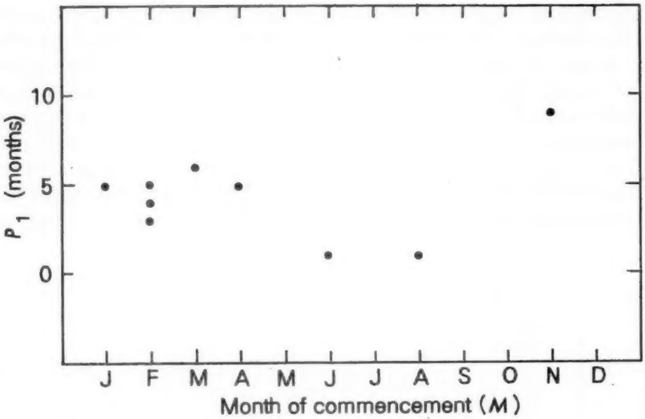

FIGURE 1—SCATTER DIAGRAM SHOWING LENGTH (P_1) OF THE INCREASING WESTERLY ARC AT 30 mb OVER CANTON ISLAND AND GAN AS A FUNCTION OF THE MONTH OF COMMENCEMENT

However, the arc which started in November lasted longer than any of the others and hence it may be said that arc lengths tend to decrease as dates of commencement vary from November to August. Figure 2 shows the scatter diagram rearranged to centre round January instead of round July. The re-arranged months of commencement were then coded as 1–12 or 13–24 and a regression equation of arc length (P_1) on month-number of commencement (M) was formed. This was $P_1 = -0{\cdot}78\ M + 16{\cdot}0$, and the correlation between P_1 and M was found to be $-0{\cdot}84$, which 'Student's' t-test showed to be significant at the 1 per cent level. Figure 2 also shows the regression line and the 99 per cent confidence limits for it.

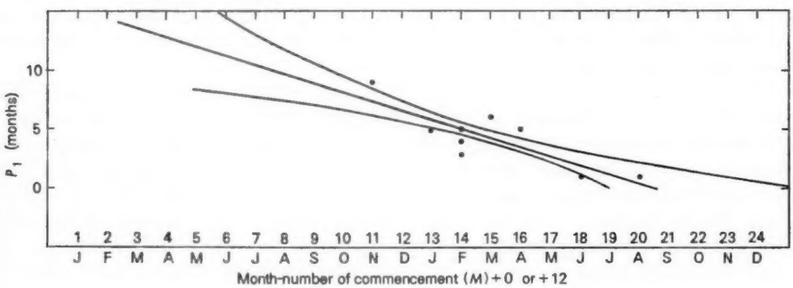

FIGURE 2—MODIFIED VERSION OF FIGURE 1 WITH MONTHS REARRANGED TO CENTRE ROUND JANUARY INSTEAD OF JULY

The regression line for $P_1 = -0{\cdot}78\ M + 16{\cdot}0$ is shown together with the 99% confidence limits.

The next part of the procedure was to replot the scatter diagram in January-to-December format and superimpose the regression line (Figure 3). Then the standard error of estimate S_p was determined by using the relationship $S_p = \sigma_p \sqrt{(1-r^2)}$, where σ_p is the standard deviation of the values of P_1, and r is the correlation coefficient between P_1 and M. Lines in Figure 3 showing twice the standard error of estimate can be assumed to envelop 95 per cent of the observations. Since the regression line from Figure 2 now appeared twice on Figure 3, a second (and in two cases a third) intercept was computed to define it fully, although of course the slope and first intercept remained the same.

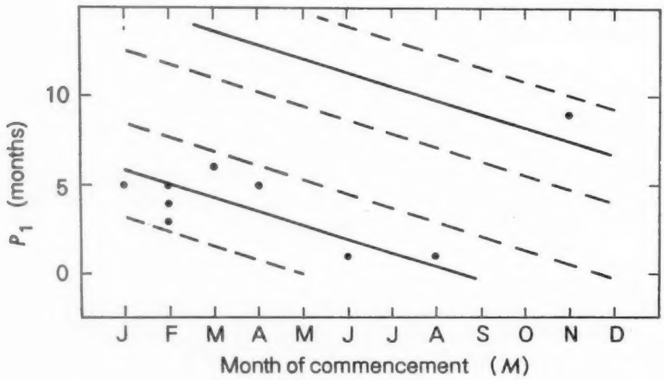

FIGURE 3—FIGURE 1 WITH SUPERIMPOSED REGRESSION LINE FOR $P_1 = -0{\cdot}78\ M + 16{\cdot}0$ SHOWN AS A FULL LINE

Dashed lines indicate standard error of the estimate (significant at the 1 per cent level by *t*-test).

These processes were repeated for all intervals to be considered and the results may be seen in Table III. In two of the intervals there is no usable relationship between P_1 and M, but in the majority it does appear that a regression line of slope slightly less than $-1{\cdot}0$ provides a reasonable explanation of the distribution, if the projection of the line beyond one December, or sometimes two Decembers, is accepted.

The same method was also used to prepare diagrams of the relationship between the month-number in which an event occurs at 30 mb and the number of months by which the same event at 50 mb lags behind it. It is interesting to note that variations have occurred in the past from the usually accepted figure for the downward transmission of events of 1–2 km per month (Ebdon (1963) and Böhme (1969)). The time taken for the change from westerly to easterly, for instance, to propagate from 30 to 50 mb varied between 2 and 12 months—a rate of between about 0·3 and 1·5 km per month. It seems possible that Table IV may be of more assistance in predicting dates of 50-mb events than the value of 1–2 km per month, at least for the change-overs and D_{wmax}, which are significant at the 0·1 per cent level by application of the *t*-test.

The investigation thus far has dealt with the QBO in the monthly mean zonal wind component. The QBO may also be traced in the temperature anomalies

at the same levels, although the month-to-month variability is much greater than that of the wind component. However, an inspection of the data showed that dates of change-over from negative to positive and positive to negative anomaly, and (to a smaller extent) of maximum positive and maximum negative anomaly

TABLE III—RELATIONSHIP BETWEEN THE LENGTH OF A PERIOD (P_1) AND THE NUMBER OF THE MONTH IN WHICH IT BEGAN (M)

	Interval	*m*	c_1	c_2	c_3	Standard error of estimates *months*	*r*	Significance level *per cent*
30 mb		−0·78	16·0	6·7	—	1·3	−0·84	1
		−0·80	23·2	13·6	—	1·8	−0·84	1
		−0·47	14·9	8·4	—	1·4	−0·81	1
		−0·88	32·7	22·2	—	1·9	−0·89	1
		−0·63	15·5	8·0	—	1·3	−0·73	5
		−0·88	25·1	14·6	—	1·9	−0·79	2
		−0·75	24·1	15·1	—	1·9	−0·77	2
		−0·92	38·6	27·5	—	2·1	−0·87	1
		−0·89	37·5	26·9	—	1·9	−0·90	1
		−0·96	42·5	31·0	—	1·7	−0·93	0·1
		−0·82	43·1	33·3	—	2·1	−0·83	1
50 mb		−0·69	14·9	6·6	—	0·9	−0·97	0·1
		−0·84	17·2	7·2	—	1·5	−0·91	0·1
		−0·28	10·7	7·4	—	0·9	−0·86	1
		−0·31	8·0	4·3	—	0·6	−0·80	1
		−0·58	23·4	16·5	9·5	0·8	−0·99	0·1
		−0·65	15·7	7·9	—	0·8	−0·96	0·1
		−0·88	29·2	18·7	—	1·4	−0·94	0·1
		−0·92	40·9	29·9	—	1·8	−0·91	1
		−0·89	41·4	30·7	—	1·4	−0·94	0·1
		−0·84	40·1	30·0	19·9	1·6	−0·96	0·1
		−0·74	35·6	26·8	—	2·2	−0·83	1

m, c_1, c_2 and c_3 refer to the regression equation $P_1 = mM + c$, with c_1, c_2, c_3 being the values appropriate to the separate portions of the regression line (see Figure 3 and text). The equations for the increasing westerly arc at 30 mb are thus $P_1 = -0{\cdot}78\ M + 16{\cdot}0$ and $P_1 = -0{\cdot}78\ M + 6{\cdot}7$, and the equations for the 95% confidence limits for the first of these are $P_1 = -0{\cdot}78\ M + 16{\cdot}0 \pm (1{\cdot}3 \times 2)$. The correlation coefficient r and the significance level from 'Student's' t-test are also shown.

could be selected in a reasonably objective manner. The histograms of occurrence in each month (not reproduced here) showed a tendency to favour one half-year in preference to the other, as did those for the zonal wind component, and this was taken as an indication that a relationship between the month in which a temperature event occurred and the number of months later that the accociated wind event took place might be established. To assist in the examination of this relationship a further set of scatter diagrams was plotted. Negative-to-positive ($-$ to $+$) temperature changes were taken to be associated with the following wind changes from easterly to westerly, and so on.

Much the same procedures used for the wind events were followed for temperatures, and Table V gives details of the results obtained, where $D_{\max+}$ and $D_{\max-}$ are the dates of occurrence of maximum positive and maximum negative temperature anomaly.

At 50 mb the relationship between D_{Wmax} and $D_{\max+}$ appears to be useful ('Student's' t-test gives 0·1 per cent probability), and at 30 mb the relationships between D_{Wmax} and $D_{\max+}$, D_{Emax} and $D_{\max-}$ and between $D_{\mathrm{W-E}}$ and $D_{+ \text{ to } -}$ all seem to be worthy of consideration, with t-test probabilities of 1·0, 0·1 and 0·1 per cent respectively.

Diagrams constructed from Tables III, IV and V being given, the procedure for producing a forecast of the dates of future events is very simple. Suppose that it is desired to estimate dates of events for a whole cycle. The method adopted is to use the dates of the preceding 30-mb events (at cycle, half-cycle, phase or arc intervals before the event that one wishes to forecast) and, from the diagram for Table III, to estimate the length of the period appropriate to the month of commencement. This will give a range of likely dates which may be used in the arc forecast of the next event and the phase or half-cycle forecast of the one after that. Inconsistencies between estimates of the date of a particular event arrived at from three different intervals are eliminated before proceeding to the next date, greater weight being given to the more reliable relationships. The diagram for Table V may then be used to narrow the range of dates further for some of the events.

When the 30-mb forecasts are completed the same process is applied to the 50-mb data, and here one may also use the diagram for Table IV for all events except the occurrence of maximum easterly component, $E_{\max}$, again adjusting towards the more significant results.

By using an earlier variant of this method a forecast was made in October 1973 of the dates of the events in the next cycle, and Figure 4 shows the results of this so far. At 50 mb the dates of the change-overs were accurately forecast within what for most purposes would be an acceptably small range. The value of D_{Emax} was badly in error but the associated zonal wind component was only some 5 kn stronger than a secondary maximum which occurred in the middle of the forecast range.

At 30 mb the zonal component changed from westerly to easterly much earlier than expected, and even a subsequent hesitation in the weak easterlies did not really allow the suggestion that this forecast was anything but a failure. The value of D_{Emax} and in particular the value of $D_{\mathrm{E-W}}$, however, were well predicted, even though the range of dates expected was larger than one could wish.

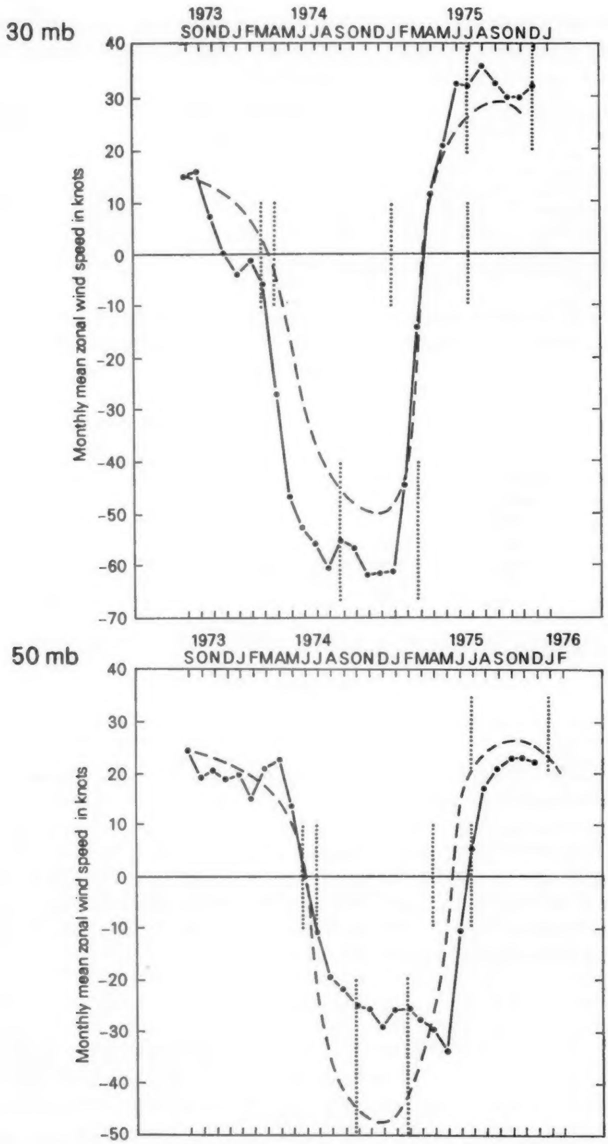

FIGURE 4—FORECAST AND ACTUAL DATES OF CHANGE-OVER AND D_{Emax} AND D_{Wmax} FOR GAN FOR 30 mb AND 50 mb

·——· actual dates — — — forecast dates

The forecast was made in October 1973 and produced times of events delineated by a range of months shown as vertical dotted lines. The forecast curve (— — —) was then added to show clearly the expected sense of the change, with no attempt to predict actual values. Positive values of zonal wind speed denote westerliness and negative values easterliness.

TABLE IV—RELATIONSHIP BETWEEN THE MONTH IN WHICH AN EVENT OCCURS AT 30 mb (M) AND THE NUMBER OF MONTHS LATER THAT A SIMILAR EVENT OCCURS AT 50 mb (P_2)

Event	m	c_1	c_2	Standard error of estimate *months*	r	Significance level
W_{max}	−0·76	15·5	6·3	1·4	−0·95	0·1%
W–E change-over	−0·78	16·1	6·8	1·1	−0·90	0·1%
E–W change-over	−0·22	6·1	3·5	0·3	−0·90	0·1%

See Table III for explanation of symbols.

TABLE V—RELATIONSHIP BETWEEN THE NUMBER OF MONTHS (P_3) BY WHICH WIND EVENTS LAG BEHIND TEMPERATURE EVENTS, AND THE MONTH OF THE TEMPERATURE EVENT (M)

Zonal-wind event	Temperature-anomaly event	m	c_1	c_2	Standard error of estimate *months*	r	Significance level
50 mb W_{max}	max+	−0·67	14·4	6·4	1·2	−0·94	0·1%
30 mb W_{max}	max+	−0·82	16·4	6·6	1·9	−0·82	1%
E_{max}	max−	−0·59	15·7	8·7	1·2	−0·93	0·1%
W–E change-over	+ to −	−0·80	12·7	3·1	1·7	−0·90	0·1%

See Table III for explanation of symbols.

Of six verified results, then, only one was totally unacceptable, one was marginally so and four were good.

It is suggested that the relations between dates of events in the stratosphere at Gan and lengths of subsequent intervals may serve as a basis for forecasting dates of events up to a cycle in the future. The forecast need not apply exclusively to Canton Island and Gan, since Böhme (1969) states unequivocally (para 2.1.1) that 'independently of longitude each phase (e.g. the westerly-wind maximum) occurs simultaneously at a given height and latitude'.

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ACOUSTIC SOUNDING OF A SEA FOG

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SUMMARY

The appearance of a spring sea fog on the record of an acoustic sounder situated near the north-west coast of England is discussed speculatively in terms of atmospheric mechanisms in and above the fog layer. Acoustic and visual evidence for the presence of convection in the fog layer is mentioned, as is acoustic evidence for the presence of a neutrally buoyant region in the upper part of the layer, and a dynamic though statically stable layer above.

In the early afternoon of 5 March 1975 a bank of sea fog rolled inland from the Irish Sea over an acoustic sounder operating beside Lancaster University. Although many examples of acoustic-sounder records have been published while the technique has become established over a period of seven years (for example, McAllister *et alii*, 1969 and Bean *et alii*, 1973) we have been unable to find any reports associated explicitly with foggy conditions, though we would guess that there must have been fog in some of the cases of strong nocturnal cooling (Wyckoff, Beran and Hall, 1973); however, even if the latter were foggy, such layers chilled from beneath were statically stable. By contrast in the present case there is some evidence that the fog was in a statically neutral or even unstable layer bounded above by a pronounced stable layer. If this was the case then the situation is similar in many respects to the mainly cloud-free convecting layer beneath the subsidence inversion of an anticyclone, though on a much reduced vertical scale.

The acoustic sounder was sited 73 metres above mean sea level and 9 km east of a flat coast, and consisted of two adjacent antennae, each having a 1·5-m diameter fibre-glass paraboloidal reflector with a horn-loaded public-address speaker at the focus. The antennae acted as separate transmitter and receiver

but were sufficiently close to one another to be described as a 'monostatic'* system. At the 1000-Hz operating frequency the half-power beam width was 20°, the receiver sensitivity 100 mV Pa^{-1}, and the acoustic power output 20 W in the pulses. Pulse-repetition frequencies were 0·5 and 0·2 Hz, and the pulse length was 40 ms. The maximum receiver gain was 140 dB.

Patterns of echo strength, corrected for inverse-square effect by a range-gain compensator, and displayed on a time–height graph, are shown in Figure 1, and discussed briefly in this note. Two points should be borne in mind throughout: (1) theory (Monin, 1962) and observation strongly suggest that a monostatic acoustic sounder detects echoes from volumes of air containing turbulently

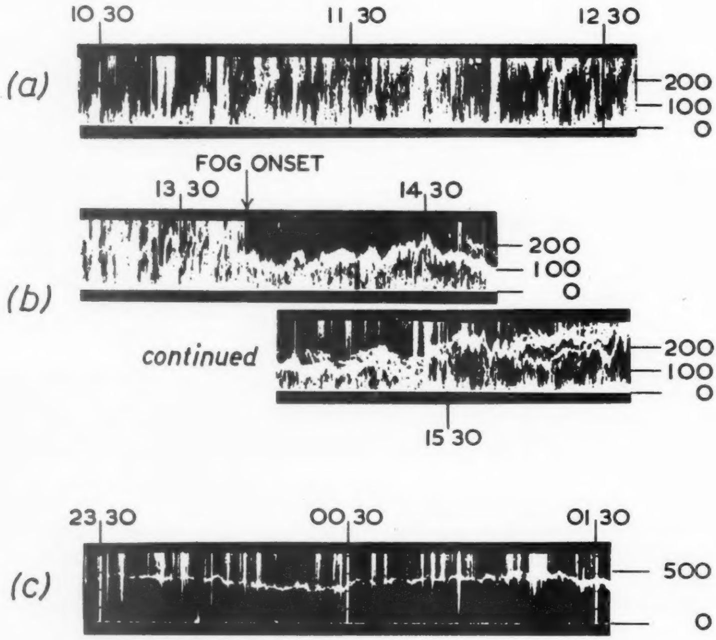

FIGURE 1—ECHO STRENGTHS AT LANCASTER ON 5–6 MARCH 1975

Signal (and noise) are white, silence is black.
Height (ordinate) is marked in metres above the sounder.
Time (abscissa) is marked in Greenwich Mean Time.
Station co-ordinates: 54°N, 2°45′W, height 73 m above m.s.l.

**monostatic:* a word used by workers in this field to describe a system in which transmitter and receiver either share the same antenna or are placed in such close juxtaposition that they can be regarded as being effectively in the same place; otherwise the system is described as *bistatic*. (Both words appear to have been invented by someone ignorant of Greek; *monotopic* and *ditopic* might be better for the purpose (Editor).)

induced temperature inhomogeneities on the scale of half the wavelength of the probing signal (15 cm in this case), and that such echoes are many orders of magnitude stronger than those to be expected from water droplets typical of fog or cloud (Little, 1972). Therefore the patterns in Figure 1 relate to the temperature field, and only in an indirect way to the presence of fog droplets. (2) spikes of 'echo' extending down from the top of the sounder record (most obvious in Figure 1(c)) represent noise, probably from the nearby motorway, which is enhanced with increasing height by the range-gain compensator.

Figure 1(a) shows echo patterns recorded by the Lancaster sounder on the morning of 5 March 1975, that is to say before the arrival of the fog. Mostly clear skies allowed strong solar heating to produce an unstable (superadiabatic) layer close to the ground in a north-westerly flow from the sea about 9 km away. Although some 50 km south-south-east of the sounder, the noon radiosonde ascent from Aughton near Ormskirk (Figure 2) penetrated a similar airflow and showed that the first 14 mb (about 140 m) of the atmosphere had a super-adiabatic lapse rate. The 'tufts' of echo apparent in Figure 1(a), extending upwards from near the surface to heights varying between 60 and 200 m, are typical of sounder records obtained in convection from the surface, which have been shown (Beran, Little and Willmarth, 1971) to represent plumes of rising, thermally inhomogenous air.

At about 1330 GMT visibility at the sounder began to deteriorate; the site was enveloped by swirling fog at 1340 and in the following half hour temperatures at screen level and at 30 m fell by 2 deg. Figure 1(b) shows that the echo pattern on the sounder record changes strikingly at about 1340 GMT; echo tufts are replaced by a fairly uniform 'grass' apparently contained beneath a reflecting layer centred at about 150 m, a height which agrees well with visual estimates of the top of the patchy fog. From the detailed appearance of the sounder record (which has not copied well from the film original) we believe that the grass represents convective elements with horizontal dimensions much smaller than the 600 m typical of pre-fog conditions (calculated on the assumption that plumes etc. have been moving with the wind at the 3-m level, where the speed remained close to 5 m/s for much of the day). Visual observations from ground level of the patchiness of the fog, and its occasionally broken and hummocky upper surface, further suggest the presence of some type of convection. This could have been produced by residual static instability in the cool fog layer as it overran the previously warmed surface, or it might have been maintained mechanically in a nearly but not exactly neutrally stable fog layer.

From many reports (McAllister *et alii*, 1969) it is well established that a horizontally continuous reflecting layer, such as that centred at 150 m in Figure 1(b), corresponds to a pronounced stable layer. Just such a layer was apparent between 140 m and 460 m above Aughton at 12 GMT (Figure 2) but it is clear from Figure 1(b) that though there is evidence of a weakly defined layer between heights of 100 and 200 m at Lancaster before 1340 GMT, this layer strengthened, lowered, and steadied with the arrival of the fog beneath. The mechanism of this change is obscure, and presumably involves effects localized in the north Irish Sea and surrounding land which produced the sea fog (that is to say, which produced the cool saturated layer beneath the stable layer), as well as larger-scale events maintaining the stable layer itself—notably subsidence in a weak ridge ahead of a warm front advancing from the west. The virtual absence of echo from higher levels is to be expected, since the stable layer inhibits the upward

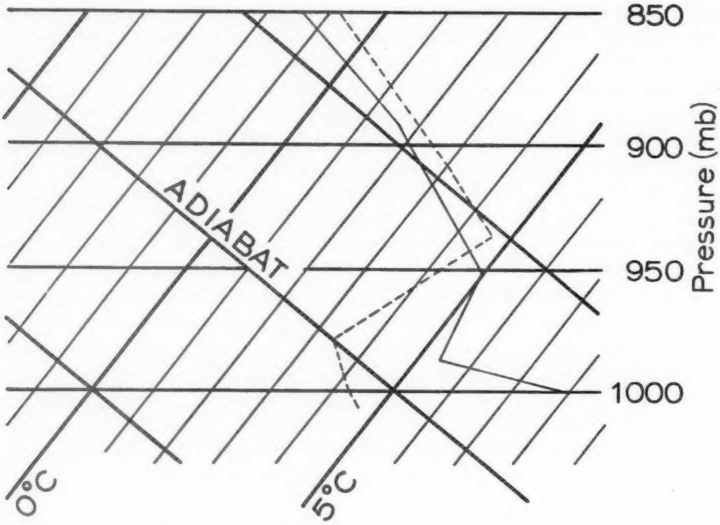

FIGURE 2—TEMPERATURE SOUNDINGS FROM AUGHTON DISPLAYED ON A TEPHIGRAM

Solid line 12 GMT, 5 March 1975.
Dashed line 00 GMT, 6 March 1975.
Station co-ordinates: 53° 33′N, 2° 55′W, height 59 m above m.s.l.

extension of turbulence generated in lower layers, but the sharpness of the upper boundary at the reflecting layer (i.e. of the population of temperature inhomogeneities) cannot be explained in simple terms; it is probably related to the production of turbulence by shear instability within the stable layer, and is evidence of structure on a vertical scale smaller than that of the stable layer itself. Such structure has been investigated by radar (Browning, Starr and Whyman, 1973) and further acoustic evidence is discussed below.

At 1540 GMT the fog became much more patchy and the sun began to break through quite frequently. Figure 1(b) shows that the reflecting layer began to lift at about the same time, subsequently varying about the 200-m level in occasionally obvious concert with the now more clearly visible plumes underneath. The echo-free layer between the plume tops and the stable layer, apparent in much of the afternoon's record, is consistent with volumes of relatively warm air rising and overshooting through a region in which they are neutrally buoyant. At about 1600 GMT the reflecting layer split into two layers separated by an echo-free layer some 40 m deep. This accords with radar observations cited above (which refer to anticyclonic subsidence inversions overlying convective layers) and the recently proposed theory (Pellacani, C. and Lupini, R., unpublished) that gravity waves trapped in a stable layer capping a convective layer can grow by resonance with convective perturbations until they break down into layers of turbulence localized in the upper and lower levels of the stable layer.

After the period covered by Figure 1(b) the reflecting layer rose slowly, reaching a height of about 400 m by midnight (Figure 1(c)). This is consistent

with the midnight sounding from Aughton (Figure 2), remembering the considerable separation of sites, and with the approach of the warm front. The reflecting layer was still pronounced, and since there were no underlying plumes, this suggests that at least a substantial part of the acoustically effective turbulence in the stable layer throughout the day was not produced by overshooting plumes, the source being presumably shearing instability of some type.

Acknowledgements

A.C.L. and N.E.H. acknowledge the award of N.E.R.C. studentships and research associateships respectively during the course of the work. All of us wish to acknowledge the role of Dr D. G. Felgate in early design and construction of the sounder during his tenure of an N.E.R.C. research fellowship at the University of Lancaster.

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AN IMPROVED WIND-DIRECTION INDICATOR

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SUMMARY

A wind-direction indicator has been constructed which has better damping response than an indicator of conventional design and is thus capable of producing more precise wind-direction data.

1. INTRODUCTION

The conventional wind-direction indicator has a vane which aligns itself with the wind direction by pivoting about a vertical axis. Standard meteorological patterns have shortcomings, particularly with regard to their dynamic characteristics (Giblett *et alii*, 1932). For many applications an approximate indication of wind direction may be acceptable, but it was considered that in experiments to determine relationships between wind and its effects on the ventilation system of livestock buildings, wind direction would be an important factor and its accurate measurement essential.

The relevant characteristics of a wind-direction indicator are:

(a) *Frequency response*. This will determine the speed with which it will move to a new equilibrium position in response to a shift in wind direction.

(b) *Damping*. This is essential so that any oscillatory tendencies are quelled in a predictable manner. In the design to be described particular importance is assigned to damping.

(c) *Angular resolution*. The equilibrium angular position of the indicator should always be the same as the wind direction within defined limits and furthermore this change should be registered by any associated recording apparatus.

(d) *Sensitivity*. This is the minimum wind speed necessary to move the indicator to the equilibrium position. Some standard angular deviation (usually 90°) is chosen for the initial condition.

(e) *Directional bias*. This could arise from asymmetrical construction aerodynamically or from imbalance about the pivotal axis. The latter would manifest itself if the indicator had not been correctly levelled.

(f) *Pivotal friction*. Pivotal friction could be regarded as contributory to damping, lack of angular resolution and lack of sensitivity, but it is listed here because it is fairly easy to identify and can be regarded separately as a problem of mechanical design.

2. THEORY

Mathematical expressions for the motion of a wind-direction indicator have been given (Giblett *et alii*, 1932; MacCready and Jex, 1964) but it can be shown quite easily that the criterion for critical damping or for over-damping is

$$\frac{Ka^2}{4u^2} \geqslant 1, \qquad \qquad (1)$$

where $K = (abc/I)\,(\mathrm{d}c/\mathrm{d}\alpha)\,(\rho u^2/2)$ and

$a,b,c,$ = length of rod, vane height, vane width respectively,
$\mathrm{d}c/\mathrm{d}\alpha$ = rate of change of lift coefficient with angle,
I = moment of inertia,
ρ = air density, and
u = wind speed.

The moment of inertia, I_1, of the vane only is

$$I_1 = \frac{b\sigma}{3}\left[3a^2c + \frac{c^3}{4}\right], \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (2)$$

where σ is the surface density of the vane.

The first moment T_1 of the vane is

$$T_1 = abc\sigma. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (3)$$

This is counterbalanced (usually) by a mass M on a rod of length l. Thus the first moment T_2 of the counterbalance mass is

$$T_2 = Ml. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (4)$$

The moment of inertia of the counterbalance mass is

$$I_2 = Ml^2. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (5)$$

If the effects of any support rod are neglected, then from equations (3) and (4)

$$M = \frac{abc\sigma}{l}, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (6)$$

whence from equation (5)

$$I_2 = abc\sigma l \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (7)$$

and the total moment of inertia is

$$I = I_1 + I_2 = \frac{b\sigma}{3}\left[3a^2c + \frac{c^3}{4}\right] + abc\sigma l. \quad \ldots \quad (8)$$

Some numerical values can now be taken into account. Putting $\rho = 1{\cdot}22$ kg/m^3, using the following expression for $\mathrm{d}c/\mathrm{d}\alpha$ (Royal Aeronautical Society, 1970)

$$\mathrm{d}c/\mathrm{d}\alpha = (0{\cdot}34\; b/c) + 2{\cdot}25, \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (9)$$

and choosing $l = a/4$, then expression (1) becomes

$$\left[0{\cdot}34\;\frac{b}{c} + 2{\cdot}25\right] a \geqslant \left[8{\cdot}20 + 0{\cdot}55\;\frac{c^2}{a^2}\right] \sigma. \quad \ldots \quad \ldots \quad (10)$$

Now the highest value of the ratio b/c that can effectively alter $\mathrm{d}c/\mathrm{d}\alpha$ is about 20. Expression (10) then becomes

$$a \geqslant \left[0{\cdot}91 + 0{\cdot}06\;\frac{c^2}{a}\right] \sigma. \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (11)$$

A light-alloy vane is unlikely to have a surface density of much less than 2 kg/m^2. Thus if c is negligible, expression (11) shows that $a \geqslant 1{\cdot}8$ m. It would therefore appear that provided that the ratio b/c is about 20 the device should be well damped whatever the values of b or c when the length of the support rod is about 2 m.

Abandonment of the counterbalance mass and using expressions (1) and (2) yields a similar criterion ($a \geqslant 1{\cdot}44$ m). Thus the counterbalance mass would appear not to alter the design greatly but it obviates directional bias due to faulty levelling and also distributes the load more uniformly on the central bearing. Aerodynamic effects of counterbalance weights have been considered in detail (MacCready and Jex, 1964) but it was considered that in the present context these would be small and could be neglected. There is probably some advantage in not achieving critical damping, but rather to have one extra overshoot in response to a stepwise change in wind direction, because this involves less time in settling to equilibrium. This would also enable the support rod to be shortened somewhat. In the design to be described it was found that the rod could be shortened considerably while retaining acceptable damping characteristics.

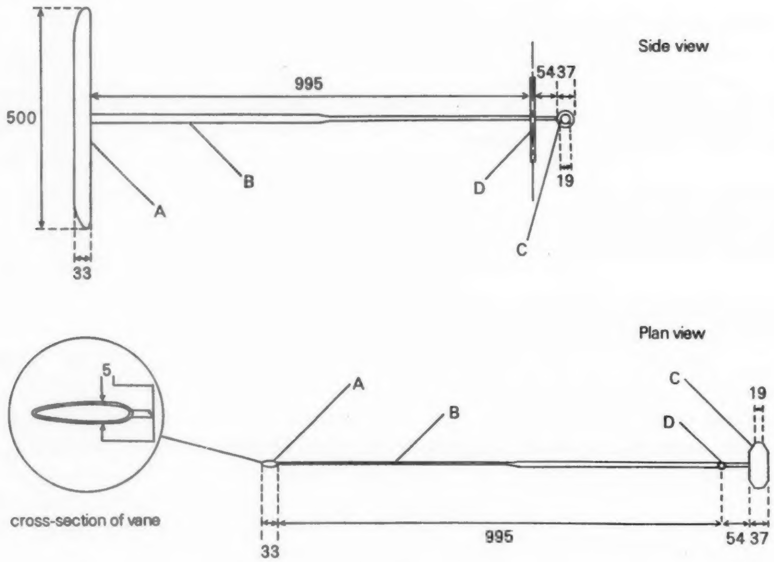

FIGURE 1—SIDE AND PLAN VIEWS OF EXPERIMENTAL WIND INDICATOR

(See text for explanation of letters A–D.)

3. Description

A wind-direction indicator as shown in Figure 1 was constructed in the light of the criteria outlined above. The essential steps in the process were:

(a) The vane (A) was constructed by almost flattening a tubular aluminium extrusion of approximately 0·51-mm wall thickness, trimming the ends as shown to make them curved, and finally sealing the tube by welding.

(b) The vane was glued with epoxy resin to the support rod (B) which was also made from an extruded aluminium tube of 0·51-mm wall thickness. About half-way between the axis of rotation and the vane the support rod was slightly flattened, the flattening increasing towards the vane.

(c) The weight of the vane was counterbalanced by a brass weight (C) machined to a cylindrical shape and mounted on the aluminium tube.

(d) The central shaft (D) was arranged to rotate in a bearing protected by an aluminium housing (not shown) which also contained a potentiometer connected to the shaft.

The design as described could only be implemented because the particular aluminium extruded sections were available; previously tubes with such thin walls were available commercially only as rolled tubes, which have a lower strength.

4. Tests

The wind indicator was tested together with a Meteorological Office Mk III direction indicator in the laboratory and out of doors. In the laboratory test the wind indicators were set up in an airstream and released from a deflexion angle of 30° in such a way that they resumed their alignment with the direction of the airstream. The angular deflexion at any instant during this process was determined from high-speed recorder charts of the voltage across the potentiometer. Refinements in the design were achieved progressively by modification followed by tests to produce the indicator shown in Figure 1. The sensitivity of the indicator was assessed by releasing it from a deflexion of 90°.

In the out-of-doors test both instruments were at a height of 5 m. Their angular movements were recorded by a chart recorder in the laboratory. In addition the behaviour of both indicators in relation to that of smoke plumes generated upstream was observed visually.

5. Results

It was found that the tendency of the indicator to overshoot was reduced as the vane was flattened. Since the purpose of using tubular materials for the vane was to provide rigidity in planes normal to the vane it could not be made entirely flat. The partial flattening of the support tube near to the vane had an observable effect as had the shaping of the ends of the vane. A satisfactory compromise between position and weight of the balance weight was found empirically. Smaller weights further from the pivot were shown to affect the performance adversely by increasing the moment of inertia, whereas larger weights closer to the pivot became cumbersome. In an original version the weight was in the form of a massive tube similar in shape and size to that shown in Figure 1, but

threaded over the support rod. A definite improvement was achieved by fixing it at right angles to the support rod, thereby concentrating its mass with respect to its distance from the axis, thus reducing its moment of inertia.

The result of a typical laboratory test on the final version of the indicator is shown graphically in Figure 2, together with the results for the Mk III indicator. It can be seen from Figure 2 that the experimental indicator was less than critically damped, giving one overshoot, whereas the Mk III indicator exhibits at least four overshoots beyond the equilibrium position. Also the experimental indicator finally reaches the equilibrium position within 2·5 seconds. The Mk III indicator is still oscillating after 6 seconds. Equation (1) shows that the condition for critical damping is independent of wind speed. This point was not investigated for the experimental indicator owing to limitations of the laboratory apparatus. However, only one overshoot was observed at all wind speeds lower than 3·8 m/s. Although the theory is strictly applicable only to small deflexion angles (Mazzarella, 1972) the observed behaviour of the indicator suggests that it can be used as an effective guide to design. The rather large initial deflexion angle of 30° was chosen to illustrate the ability of the indicator tor each equilibrium quickly. The comparison with the Mk III indicator is tentative; the latter may be preferable at higher speeds and for prolonged exposure in rough conditions. The results for out-of-doors comparisons are mentioned but briefly

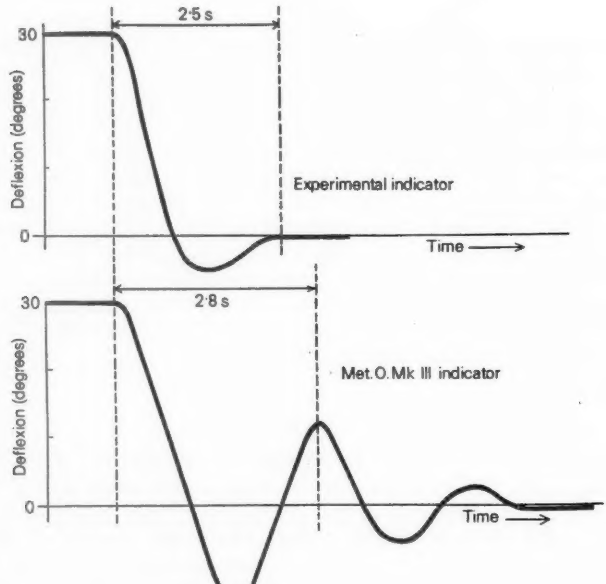

FIGURE 2—RESPONSE OF EXPERIMENTAL INDICATOR AND METEROLOGICAL OFFICE Mk III DIRECTION INDICATOR IN LABORATORY

Air speed 3·8 m/s.

since they raise questions that are outside the intended scope of this report. However, it was observed that a smoke plume typically adopted a serpentine form as it was caught up in areas of wind turbulence, and that the movements of the experimental direction indicator followed the contortions of the smoke plume much more faithfully than did those of the Mk III indicator. Thus the more frequent excursions of the chart record for the former were taken as a better indication of wind behaviour than the record for the Mk III indicator.

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THE NORTH-EAST MONSOON AND THE CAUSES OF THE WINTER RAINS OF SOUTH-EAST INDIA

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SUMMARY

Examination of meridional sea-level pressure profiles over India, the Atlantic and Pacific and of winter rainfall over India and Sri Lanka demonstrates that the so-called north-east monsoon over south-east India differs little, either in wind or in weather, from the generality of the northern-hemisphere trade winds.

1. INTRODUCTION

It is often mentioned that the winter rains of south-east India are due to the north-east monsoon. Though the winter monsoon is originally dry, it is supposed to acquire enough moisture before blowing over the eastern parts of peninsular India because of its travel over the Bay of Bengal. Gaspar (1962), in the introductory remarks to his study of the rains over Madras State, associated these rains with the north-east monsoon. Thiruvengadathan (1965) proposed different types of upper-air flow patterns as being responsible for spells of strong and weak north-east monsoon conditions defined in terms of the rain. The concept of a north-east monsoon over south India is thus not only accepted but its characteristics are being studied, much on the lines of the rainy south-west monsoon.

The word 'monsoon' was originally used for the 180° change in direction of the prevailing winds over the Arabian Sea from winter to summer and vice versa. During summer the sea-level circulation over Asia, particularly in the

southern region, is dominated by the heat low centred over Arabia and north-west India. In winter, however, the Siberian anticyclone dominates the circulation over Asia. These pressure- and wind-systems, which are the result of differential heating of land and sea, have been accepted as accounting for the monsoonal phenomena over India and surrounding areas.

Flohn (1960) suggested that the monsoonal kind of wind changes observed in the tropics and subtropics can also occur on a completely land-covered globe owing to the seasonal variation of the solar radiation. He concluded that the physical causes of monsoonal winds are to be found not only in the differential heating of land and sea but also in the thermally controlled seasonal migration of the planetary pressure- and wind-belts in the continental sections of the globe.

It later became customary to call the prevailing wind in summer the 'summer monsoon' and that in winter the 'winter monsoon'. The summer monsoon in India, because of its rain-bearing nature, has suffered a complete shift in its meaning, and is now used for the associated rains. A 'weak monsoon' thus means scanty rainfall over the country, and an 'active monsoon' means widespread heavy rainfalls. This usage, however, has gradually started to spread to the winter north-east monsoon, as has previously been stated. This trend in the shift of the meaning of 'monsoon' has engendered a misconception that the winter north-easterlies over south India are very different from the north-east trades over the rest of the tropics. The following observations show the contrary to be the case.

2. Meridional pressure profiles

The meridional sea-level pressure profiles for January along 80°E over India and along 105°E, which passes through the centre of the Siberian anticyclone, and two more, one through the mid Atlantic and the other over the Pacific, are presented in Figure 1. These profiles are prepared from the hemispherical charts given by Godske *et alii* (1957). The profiles over both the oceans show similar characteristics. The maxima at 30°N correspond with the subtropical high-pressure belt, and the minima at 55°N and 60°N over the Pacific and Atlantic with the Aleutian and Icelandic lows respectively. The pressure in the subtropical ridge over the Atlantic is greater than that in the Pacific by about 6 mb. In the equatorial regions a similar difference, but of magnitude 3·5 mb, is present. Consequently the Atlantic trade on the average could be stronger than its Pacific counterpart. An estimate of the average strength of the trade wind in the Atlantic in the latitude belt 10°–20°N can be made from Figure 1, assuming balanced motion among the pressure-gradient, Coriolis, and frictional forces. The frictional force was incorporated in the calculations by assuming an angle of 30° between the wind and the isobars, and the trade-wind strength came to about 8 m/s. A similar calculation for the Pacific winds gave a strength of 5·3 m/s. These values agree fairly well with those obtained by Riehl (1954) from actual wind values, which lends support to the accuracy of the pressure profiles presented in Figure 1. While the pressures in the Atlantic are higher than those in the Pacific at the corresponding latitudes, the pressure difference in the subtropical ridge is greater than at any lower latitude. This shows that the subtropical anticyclone in the Atlantic is somewhat more intense than its counterpart in the Pacific.

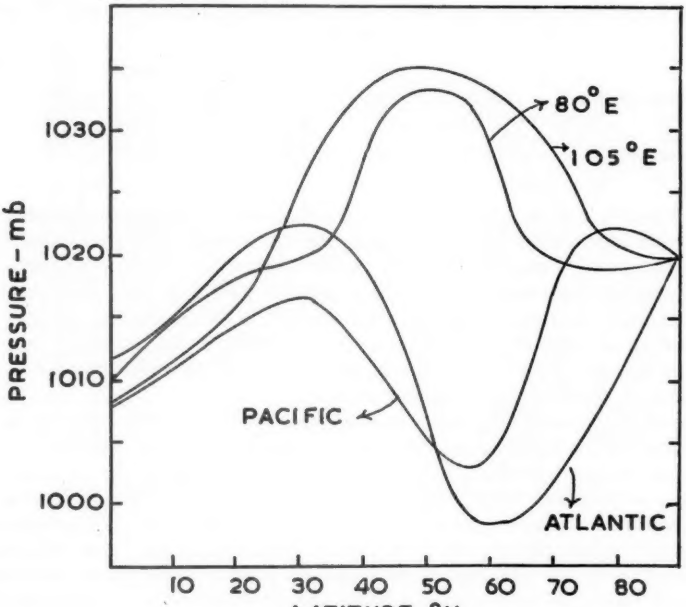

FIGURE 1—MERIDIONAL PRESSURE PROFILES

The pressure profiles along 80°E and 105°E show maxima at latitude 50°N which are due to the Siberian anticyclone. The subtropical ridge at 105°E is completely masked by the continental high. However, at 80°E the subtropical ridge is revealed by the inflexion of the curve at 30°N. South of 20°N both the curves run more or less parallel to the profiles over the oceans, and the resulting winds cannot differ much from those over the oceans. The effect of the continental high is practically confined to latitudes north of 20°N. It is apparent that in the vicinity of longitude 105°E easterly flow occurs instead of the usual westerlies in the latitude band 30°–50°N. It is therefore proper to consider these easterlies as the winter monsoon, but the easterlies south of 20°N may not be treated as being different from the trades.

3. Rainfall over south peninsular India

The mean monthly rainfall amounts (September to February) at some of the stations on the east coat of peninsular India and Sri Lanka expressed as percentages of the annual rainfall are presented in Table I. Maximum rainfall at Visakhapatnam occurs in the month of October and it shifts to Pamban in November and to Trincomalee in December. The trend of the values indicates that the maximum should be further south of Trincomalee in January and February. The gradual shifting of the heaviest rainfall to the south, from October to February, and the simultaneous southward movement of the equatorial

TABLE I—MEAN MONTHLY RAINFALL EXPRESSED AS A PERCENTAGE OF THE ANNUAL RAINFALL

		Sept.	Oct.	Nov.	Dec.	Jan.	Feb.
Visakhapatnam	(18°N)	16·8	26·4	8·8	1·6	0·8	1·6
Madras	(13°N)	8·8	20·8	24·0	12·0	1·6	0·5
Pamban	(9·5°N)	1·6	18·4	32·0	20·0	7·2	1·6
Trincomalee	(7·5°N)	4·8	12·8	20·0	20·8	12·8	5·6

trough in this area as shown by the charts prepared by Frost and Stephenson,* which are reproduced here in Figure 2, clearly indicate that the rainfall during these months is due to the activity in the equatorial trough. Furthermore, if the so-called north-east monsoon is responsible for the rains over the Coromandel coast, the rains should be at a maximum in December and January when the north-east wind regime reaches its peak. Thus the climatological aspects of rainfall also do not accord with the view that the winter rains over the coast of Madras are due to the north-east monsoon.

The daily precipitation and sea-level pressure at some stations on the east coast and the synoptic charts of the area for the three winters 1963–65 have been examined by the author in order to make a further enquiry into the nature of winter precipitation. The precipitation and pressure variations at Madras and Trincomalee for the period 15 November 1963 to 31 January 1964 are presented in Figure 3 as an example; the precipitation is shown to have occurred when the pressures were low. The high rainfall and low pressures during the beginning of the period were due to westward-moving low-pressure systems. In the first week of December there was a cyclonic storm which moved close to the peninsular coast and then recurved to east-north-east. This gave considerable rain at Madras. Between 21 and 26 December the pressures were low, but there was no rain at Madras. During this time again there was an easterly wave in the south which gave considerable rainfall farther south over the Indian coast and Sri Lanka. In January there was no rainfall at all at Madras, and the pressure was more or less steady. Occasional precipitation occurred, however, at Trincomalee. This means that as the season advanced the synoptic systems that develop in the equatorial trough gradually receded to the south.

A correlation study between pressures at Madras and at some stations in central and northern India gave high positive correlations. This shows that the low-pressure systems in the vicinity of Madras which gave rain to that area are also associated with lower pressures over the northern parts of the country but not with the intensification of the anticyclone in that region.

4. Conclusions

The meridional pressure profile in winter over India south of 20°N is similar to those over the Atlantic and Pacific and therefore the north-easterlies over India are similar to the trade winds.

The winter rainfall over the Coromandel coast is associated with the equatorial trough, and the disturbances in the equatorial trough and the adjoining easterlies.

*FROST, R. and STEPHENSON, P. M.; Meteorology of Malaya. (Unpublished, copy available in the Meteorological Office Library, Bracknell, Berks.)

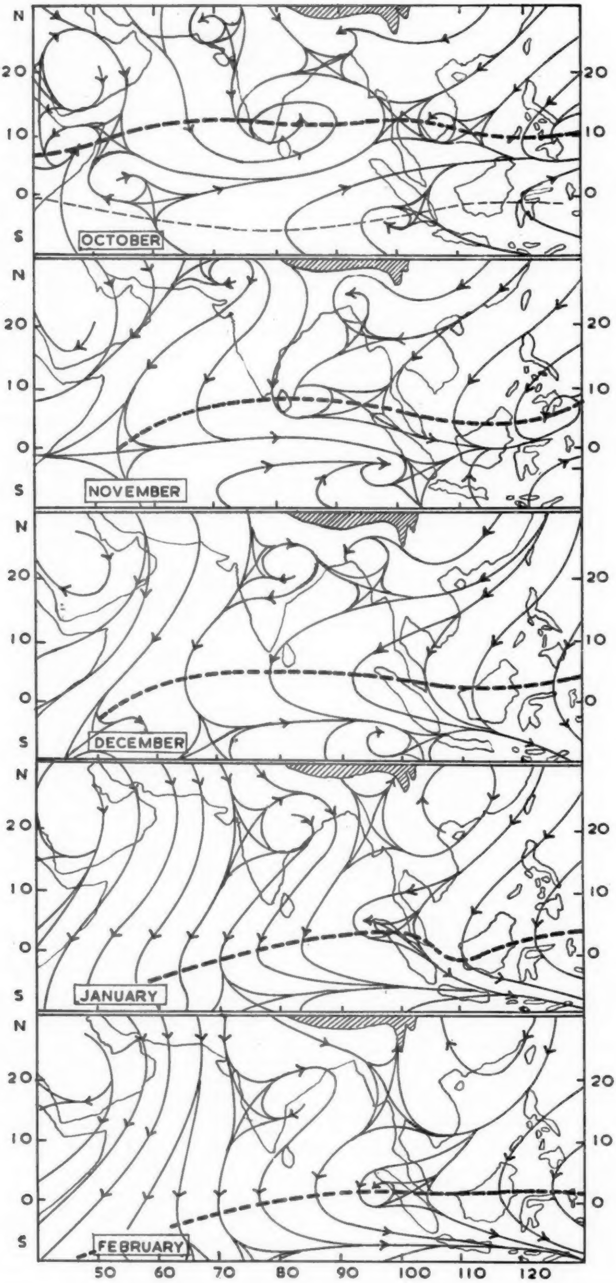

FIGURE 2—3000-ft STREAMLINE CHARTS
Dashed lines indicate equatorial troughs. (After Frost, R. and Stephenson, P. M.)

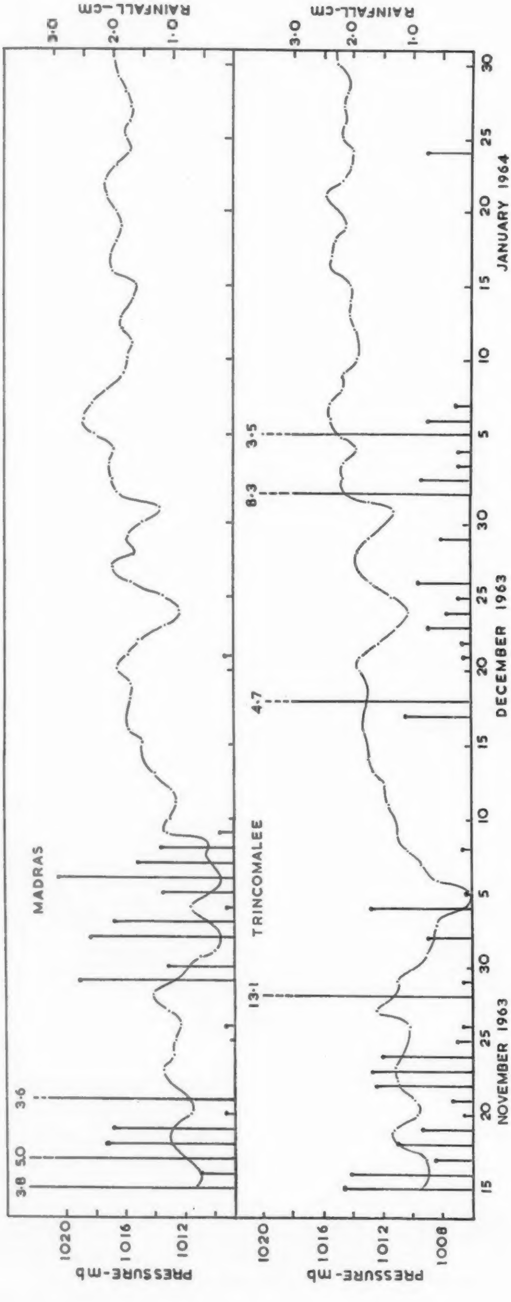

FIGURE 3—PRESSURE AND RAINFALL VARIATIONS AT MADRAS AND TRINCOMALEE, 15 NOVEMBER 1963–31 JANUARY 1964

Thus the so-called north-east monsoon over south-east India differs little, either in wind or in weather, from the trade wind as the latter is generally known and understood.

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LETTER TO THE EDITOR

Weather-spell frequencies and mathematical models

The following notes are prompted by the publication in the *Meteorological Magazine* of 'An investigation into spells of wet and dry days by region and season for Great Britain'.*

Throughout this investigation it is clear that there are difficulties in fitting the various models to frequencies of longer spells, and these results are summarized in the author's Conclusion by the statement that 'the models give only a rough guide to the occurrence of infrequent long spells'. The mathematical reason for this lack of agreement is that all the models used imply a positive persistence ($P_{(r+1)}/P_r$ increasing) whereas, in reality and except under perfectly constant conditions, spells must reach a stage where negative persistence (or anti-persistence) occurs.

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*BLAIR-FISH, J. A.; An investigation into spells of wet and dry days by region and season for Great Britain. *Met Mag, London*, **104**, 1975, pp. 360–375.

The graphically illustrated results show that negative persistence is present in the data used, for example, with wet spells at Cwm Dyli. In the Meteorological Office discussion on 'Thirty-day forecasting' (1955) Jenkinson states that anti-persistence occurs in weather spells of 15–30 days. A detailed study of runs of dry days over south-west, south-east and east England (Lawrence, 1957) shows that, during the season from June to August, persistence is positive for spells up to 8–10 days, zero or slight for spells of from 8 to 10 days to about 30 days and from then on negative. Belasco (1948) found that, for the British Isles, the probability that the next day will be anticyclonic after a run of anticyclonic days increases slightly in the range 3–20 days and thereafter shows a marked decrease.

For abnormally long spells of wet and dry weather at the several British stations examined, Newnham (1916) states that the persistence is doubtful. Persistence must depend on the regional climate (Lawrence, 1954), for example on whether the rainfall is predominantly of a showery or of an intermittent type. In more temperate regions, persistence is related to the characteristic trends of the particular season and year in question, and, for example, in an unusually dry year, negative persistence in dry-spell frequencies may not occur until spells have reached abnormal lengths. On the other hand, negative persistence could occur as a result of a weather singularity; for example, at Kew, wet early Junes tend to be followed by dry or fairly dry late Junes, a phenomenon occurring in some eight years during the period from 1871 to 1964 (Lawrence, 1965).

The concept of persistence is of basic importance in meterology because it provides a practical and comprehensible parameter or set of parameters which indicate significant differences between regions, seasons, weather regimes, spell-length etc. for various definitions of spell. Thus no model can be entirely satisfactory unless it incorporates a realistic pattern of persistence.

Further attention may be usefully given to mathematical models which allow for negative persistence, particularly with reference to infrequent longer spells but greater progress might be made from a world-wide study of the natural variation of persistence. The resulting more numerous and significant universally defined constants of persistence could be applied practically to achieve more accurate objective descriptions of climate.

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NOTES AND NEWS

European Centre for Medium-range Weather Forecasts

The newest international organization for meteorology, the European Centre for Medium-range Weather Forecasts (ECMWF) attained independent existence on 1 November 1975 when its Convention came into force. The Council, composed of representatives of the 13 States which had so far ratified, met from 4 to 6 November. Besides necessary initial formal business, the Council confirmed Dr Wiin-Nielsen as Director of the Centre, and decided on the maximum expenditures both for 1976 and for the first five years. The Headquarters Agreement with the United Kingdom, defining the Centre's legal status in the UK and the headquarters building to be provided by the UK, was also signed.

North Atlantic Ocean Stations Scheme

At the WMO informal planning meeting held in Geneva in February 1975 to produce a revised telecommunication plan for the new North Atlantic Ocean Stations (NAOS) Scheme, it was agreed that an objective should be to operate the meteorological communications by radio-teleprinter (RTT) rather than by wireless telegraphy (morse). Because of various factors, including technical compatibility of equipment, and radio-propagation problems over the North Atlantic region, it was agreed that first a series of exploratory trials would be conducted between the Russian, French and Norwegian vessels and the Bracknell shore station. These trials took place between mid September and mid December 1975. Reports on the trials are now being compiled by the participating bodies.

Meteorological effects of stratospheric aircraft

The three years' research program of the Committee on Meteorological Effects of Stratospheric Aircraft (COMESA) has been concluded and a detailed report will be produced in the near future. The results of the work indicate that the currently planned operations of Concorde aircraft in the stratosphere are not likely to result in effects on the ozone content of the atmosphere or on the climate which could be distinguished from natural variations.

Earlier calculations on the production of nitrogen oxides by heating in the shock waves associated with nuclear explosions have now been extended to include the contribution due to mixing between the hot fireball and the ambient air as the fireball rises in the atmosphere. This has been achieved by modifying a numerical model of cumulonimbus cloud to represent the nuclear cloud. The resultant findings confirm that massive amounts of NO_x, equivalent to that expected from about 1000 Concordes flying regularly, were injected into the stratosphere in past nuclear weapon testing; these massive injections produced no detectable changes in global ozone.

Acoustic sounding at Cardington

An acoustic sounder has been built and put into operation at Cardington. The sounder emits a series of narrow-beam sound pulses and picks up any returns from sharp gradients in refractive index in the overlying atmosphere. These gradients may be due to rising thermals, convectively driven turbulence, gravity

waves, or a marked temperature increase often observed at the top of the boundary layer. The returns, observed by an array of microphones, are displayed to show the variations of temperature-gradient activity with height and time above the sounder. Up to the present one of the principal difficulties has been to deduce the magnitude of the gradients from the returns with any degree of accuracy. However, the Cardington team, working in conjunction with a team from the Department of Electronics and Electrical Engineering of University College, London, have recently compared the small-scale temperature gradients inferred from the sounder with those obtained by direct measurements made by a temperature probe on a tethered-balloon cable, measuring in essentially the same air as the sounder, in both unstable and stable conditions; the agreement has proved remarkably good. Profiles of the vertical and horizontal wind speeds derived from acoustic Doppler measurements will be evaluated in a series of experiments to be carried out in the near future.

Retirement of Mr C. J. M. Aanensen

Conrad Aanensen retired from the Meteorological Office after nearly 39 years' service in March 1975—the last three-and-a-half years or so as a Higher Scientific Officer, in which capacity he had been re-engaged after stepping down on reaching the age of 61 from his Senior Principal Scientific Officer post as Head of the Meteorological Research Flight. His vitality and interest in meteorology were such that in these last three-and-a-half years he was first responsible for a valuable piece of research, namely the application of readings from the Oxford–Heriot-Watt satellite-borne radiometer on NIMBUS 4 to the construction of stratospheric charts, and later took a large part with the International Scientific Management Group in the planning of the aircraft program for the GARP Atlantic Tropical Experiment.

After graduating with high honours in Mathematics and Physics from the University of Wales he joined the Meteorological Office in 1936. He was soon forecasting at Croydon for Imperial Airways—the forerunner of BOAC, now the overseas division of British Airways, until the outbreak of the Second World War at which time there was a 'general post' within the Office, with some offices closing and others opening to serve the Royal Air Force. Aanensen found himself first at Bristol for a short time, then at Norwich for a year, followed by short spells at Gloucester and Bristol before joining the new upper-air section at Dunstable in 1943. He worked in the group dealing with radiosondes under the leadership of P. A. Sheppard, and remained associated with this work until brought down to earth on posting to Porton in 1949 to pursue research on the boundary layer—a subject close to the heart of the then Director and of his successor. He stayed at Porton for five years, gaining promotion to Principal Scientific Officer in 1950, and then joined the operational side of the Office for 12 years, successively at Bawtry and H.Q. Bomber Command. Promotion to Senior Principal Scientific Officer in 1966 saw him take charge of the Meteological Research Flight, a post which used to the full his long experience and administrative abilities.

Many will miss his kindly interest and wish him well in his retirement, which will give him time perhaps to pursue the many practical hobbies in which he is expert.

R. F. JONES

Retirement of Mr E. J. Bell

Mr Eric J. Bell, C.Eng., F.I.E.E., Assistant Director (Telecommunications) retired from the Office on 12 April 1976 on reaching the age of 60 years. His career began in the Royal Air Force where he distinguished himself in a variety of posts and attained the rank of Squadron Leader before leaving the Service in 1945. There followed a couple of years in industry during which a highlight was the 1947 Royal Tour of South Africa when Mr Bell had special communications responsibilities aboard the Royal train.

Mr Bell entered the Office on 1 January 1948 as a Signals Officer at Dunstable and was promoted to Principal Signals Officer in 1957. During the 1950s he established himself as a key figure in the telecommunications centre and played an active part in the development and reorganization of the meteorological telecommunications system in the years following the war. The period saw an increase in the use of teleprinter circuits, both land-line and radio, into Europe and elsewhere, with a corresponding decline in the volume of data gathered by reception of morse radio broadcasts and also the introduction of facsimile as an important facility for the dissemination of pictorial products. Mr Bell was also heavily involved in the complicated move of the telecommunications centre from Dunstable to Bracknell in 1961, an undertaking which posed severe technical and organizational problems but which was carried through with remarkable smoothness.

Subsequently during the 1960s the international decision to provide a high-speed trunk circuit encircling the globe and to introduce faster automated methods within regions necessitated the planning of a long-term program of modernization and automation of the Bracknell telecommunications centre. It fell to Mr Bell, following his promotion to Superintending Grade Engineer in 1971 and appointment as Assistant Director (Telecommunications) to lead the effort required to bring these plans to fruition. The implementation of this ambitious program called for considerable drive and stamina. In 1972 additional turmoil and problems were created by the move of the telecommunications centre from the Napier Shaw Wing to the new Richardson Wing, but the operation was effected with minimal interruption of the Telecommunications Branch's services to the Office.

Throughout his career of more than 28 years' service in the Office Mr Bell has been a tireless and dedicated worker with a shrewd and professional approach which has earned him a deservedly high reputation. His job has necessarily involved him in a heavy schedule of international meetings where he has become widely known and respected for his negotiating skill, sound common sense and integrity. As the head of the Telecommunications Branch he has been an indefatigable defender of the interests of his branch and staff, but even when he was arguing a case most forcibly, good humour was never very far away; he leaves the branch in a very healthy state for his successor.

In retirement one cannot imagine Mr Bell subsiding into inactivity for some time to come and no doubt he will soon be applying his talents and energy to good purposes elsewhere.

We wish Mr and Mrs Bell all possible success, health and happiness in the future. May they enjoy many years of contented retirement!

G. A. CORBY

Retirement of Mr R. E. Farms

On 21 March 1976 Mr R. E. Farms retired from the Meteorological Office after a career of over 38 years which was spent largely in the provision of meteorological services for military and civil aviation in various posts at home and overseas.

He graduated from St Andrews University in 1937 in Physics and Mathematics and joined the Office in October 1937. Before his training at Kew and Croydon was complete he left in January 1938 to serve at Heliopolis in Egypt. In 1940 he went to Habbaniya in Iraq and was granted a commission in October 1941. He subsequently served at several places in East Africa and returned to the United Kingdom towards the end of 1943. After about six months at H.Q. No. 3 Bomber Group he went in mid 1944 to Supreme H.Q. Allied Expeditionary Force, where he worked with the late Dr J. M. Stagg on the meteorological preparations for the D-Day landings of the Allied Expeditionary Force in Europe. He subsequently served at 87 Group. At the end of the war after attaining the rank of Wing Commander he was demobilized and returned to the Office as a civilian in June 1946. He spent some months in M.O.6, the branch responsible for most RAF affairs in the UK, and also in the Meteorological Office Training School which was then located in Kingsway in central London. He subsequently joined the branch responsible for overseas routes outside Europe for a spell of duty with civil aviation. In 1951 he was promoted Principal Scientific Officer and went as a senior forecaster to Prestwick, where he stayed for rather more than nine years. In 1960 he moved to H.Q. Transport Command, Upavon as Chief Meteorological Officer, and remained there until he was promoted to Senior Principal Scientific Officer in January 1971. He then went to Heathrow and stayed there until his retirement.

Mr Farms has been concerned with operational meteorological work for almost the whole of his career. His practical approach to any problem and his concern for his staff have been immediately apparent to the many colleagues who have had the pleasure of working with him during a long career. When I met him in the autumn of 1937 soon after he joined the Office I soon had experience of his prowess as a golfer and his keenness for the game when we used to play on the course which surrounds Kew Observatory. He is still very keen and plays a very good game. His many friends will wish Bob Farms and his wife a long and happy retirement.

N. BRADBURY

OBITUARY

It is with regret that we record the death on 13 February 1976 of Mr A. E. Burtonshaw, Telecommunications Technical Officer II, MetO 16.

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